Institute for Frontier Materials

Annual Report 2017

DEAKIN UNIVERSITY

IFM
INSTITUTE FOR FRONTIER MATERIALS

Geelong & Melbourne | Victoria | Australia

Year at a glance

139
HDR students

Research income
$11.2M

50 PhD
completions

319
journal articles published

224
staff, including
158 researchers

Our students
come from
24 countries

Contents

Cover: *Dr Rebecca Van Amber is part of a team using pigment from recycled denim to create new denim.*

Professor Peter Hodgson
Deputy Vice-Chancellor Research
Chair, IFM Board

Chair's report

The built environment around IFM continued to change in 2017 as a number of new industry partners joined us on site.

Over the past five years the Geelong Future Economy Precinct has created more than 1,900 jobs and more than 400 people are now employed through a 'Carbon Cluster' of businesses and research facilities on campus. This critical mass will accelerate over the coming decade, particularly as new initiatives such as ManuFutures come on board.

Our precinct on the Waurn Ponds Campus is seen as a model for other universities. We are in the unique position where start-up companies are actually growing to the next level of manufacturing and export. The embedding of cutting-edge businesses like Quickstep Holdings, HeiQ Australia and Carbon Revolution within the fabric of the University ensures that Deakin's research is focused on making a difference in the real world.

The research being carried out at IFM is very definitely in this category, with researchers and PhD students, particularly in the ARC Research Hub for Future Fibres and the ARC mineAlloy Training Centre, all working with industry partners on solving their problems and developing innovative new products and processes. In this way, Deakin researchers and students gain hands-on experience using state-of-the-art equipment for research and training. Some Deakin PhD graduates have already been employed by the companies.

The wider Geelong community also benefits, as these companies all employ local staff and the flow-on effect from collaborations with other companies and suppliers contribute additional jobs.

Another major collaboration was announced in 2017, with the licensing of carbon fibre processing technology to international company LeMond Composites in a $58M agreement. This was a significant achievement for the Carbon Nexus team and was followed by a successful Manufacturing Growth Fund application in which LeMond was awarded $2.5M towards the construction of a new carbon fibre manufacturing plant at Waurn Ponds.

The year was also important for us in the energy space, with a number of important developments, including the announcement of Deakin's $30M microgrid platform, the first advanced lithium metal pouch cells from the Battery Technology Research and Innovation Hub (BatTRI-Hub) and the award of the 2017 Victoria Prize for Science and Innovation to Professor Maria Forsyth.

The microgrid will involve installation of more than 23,000 solar panels on the Waurn Ponds Campus through a partnership with AusNet Services. The initiative will be the largest campus-based microgrid system in Australia and is a significant step towards the University's ambition to achieve carbon neutrality.

The team at BatTRI-Hub are developing the next generation of safe and reliable batteries, using ionic liquid-based electrolytes and investigating the use of sodium to replace lithium. Prof Forsyth, who was instrumental in the establishment of BatTRI-Hub, received the Victoria Prize in recognition of her pioneering work in developing advanced electrolyte materials for electrochemical devices.

Finally, I am pleased to see the strengthening of IFM's collaboration with other high quality international research institutions. Deakin University is committed to internationalisation and IFM's strategic collaborations with other institutions in India, China, the US and Europe are an important part of our growing global network. We recognise that international engagement, effective collaboration and increased global profile will be critical to future success.

$30M
microgrid platform announced

Professor Matthew Barnett
Alfred Deakin Professor
Director, IFM

Director's report

The highlight of 2017 was definitely the major licensing agreement we signed between Carbon Nexus and LeMond Composites.

The year was a dynamic one for us all and our researchers made great strides towards changing the materials world for the better.

It is a pleasure to first thank Professor Xungai Wang for his past three years at the helm of IFM. He has left IFM in a great shape, enabling us to present a great annual report for 2017. Xungai completed his three-year term in December, when he took up a wider University role as Pro Vice-Chancellor, Future Fibres. Fortunately for us, Xungai will still remain as one of the leading professors in IFM.

Here are some highlights.

In 2017, we exceeded our research income targets, particularly in Category 1 ($5.7M). Category 2-4 income was also above target ($6M). IFM maintained the excellence of its publication profile, disseminating 79% of its 343 Scopus listed outputs in Q1 journals (journals ranked in the top 25% of SJR listed journals). More papers were published with international co-authors (59%) than in any of the previous four years (maximum 50%). This reflects a growing internationalisation of our research.

Our research for the multi-billion dollar mining equipment sector stepped up a gear with the launch of mineAlloy – the ARC Training Centre in Alloy Innovation for Mining Efficiency. mineAlloy is Deakin's first ARC Industrial Transformation Training Centre. The Future Fibres Hub team working with the Ear Science Institute of Australia was awarded a $3.7M grant from the Wellcome Trust to take their silk-based membrane materials for perforated eardrum repair to the clinical trial stage. In April, five IFM researchers received a major award from the H&M Foundation in Sweden for a project to recycle denim. The award generated a great deal of media coverage, both local and international.

IFM researchers Prof Lingxue Kong and Dr Ludo Dumee were part of a successful new ARC Research Hub for Energy-efficient Separation led by Monash. Dr Dumee was also awarded a prestigious ARC DECRA Fellowship, one of only four Deakin researchers to receive the award in 2017.

Among the many awards that IFM researchers received in 2017, Prof Maria Forsyth was recognised for her pioneering work in developing advanced electrolyte materials for electrochemical devices with the Victoria Prize for Science and Innovation. A/Prof Rimma Lapovok received a Marie Curie fellowship to continue her research in hybrid materials at Technion, Israel for two years.

This year we were particularly happy to host Mr James Ouellet in October to work with Dr Christopher Hurren and Dr Liz de Rome in the field of motorcycle safety research. Prof Vijay Srivastava of the Indian Institute of Technology, Varanasi visited the composites group in December to develop future research collaborations. We also appreciated visits from our regular international metals colleagues Professors Hutchinson and Duncan.

International Activities

As part of Deakin University, IFM researchers work on an international stage with industry and research partners from across the globe. The following are some highlights of international activities in 2017.

China

Visits

A number of delegations from China visited IFM in 2017, including the following:

- China Nature Science Foundation led by deputy Director Prof Ruiping Gao
- Baosteel, led by Prof Pijun Zhang, Fellow of China Baowu Group
- Chinese Academy of Tropical Agricultural Sciences (CATAS) led by Vice President, Prof Jianghui Xie.

$1M project with India to produce new high-performing alloys

New projects

- Continuing our long-standing collaboration with the Wuhan Iron and Steel Corporation (WISCO), two new projects were initiated in 2017. The first, led by Dr Ilana Timokhina aims to enhance steel performance through an innovative approach using clusters/interface strengthening mechanisms. The benefit of this project lies in the potential to produce material that can satisfy conflicting requirements from manufacturers such as: safety, emission regulations, structures reinforcement, weight reduction and high strength and formability. The second project, led by Dr Matthias Weiss, is investigating flexible roll forming of high strength steels, for the low volume production of light weight components for the truck and automotive industry. These two projects have been funded for a total of $500,000.
- Following a successful pilot study, a technology for air pollution control developed by IFM researcher, Dr Jinfeng Wang is being scaled up for possible commercialisation by Jiangsu BOHN Environmental Protection Science and Technology Co Ltd ($140,000).
- A new project with Seeyao Electronics Co Ltd will investigate ways to improve the quality of reflective coating on car lamp reflectors ($200,000).
- Five new PhD scholarships from Wuhan Textile University for students to study at IFM ($100,000).

Research partnerships

- A delegation led by Deakin University Vice-Chancellor, Prof Jane den Hollander and Deputy Vice-Chancellor Research, Prof Peter Hodgson, visited Jilin University and signed a MoU in June 2017. Another MoU was signed in December to establish a joint Jilin and Deakin Research Centre on Materials.
- A delegation led by the Vice-Chancellor and Deputy Vice-Chancellor Research also visited Dalian Polytechnic University and signed a MoU to establish a joint laboratory on materials research.
- An application to establish an Australia-China Joint Research Centre for Materials Manufacturing has been submitted to the Australia–China Science and Research Fund ($1M).

India

New nano-tech lab for TERI

IFM researchers will co-supervise a number of students at the TERI-Deakin Nanobiotechnology Centre in Gargaon, India. A new facility at the centre was opened in April by Indian Prime Minister Narendra Modi and Australian Prime Minister, Malcolm Turnbull. The centre is a partnership between Deakin and The Energy and Resources Institute of India (TERI).

The new facility will improve research focused on global concerns, including water quality, waste management and efficient agricultural practices.

Australia–India project success

A project funded by the Australia-India Strategic Research Fund (AISRF) in 2016 on new materials for large-scale, high-performance batteries has been successful in development of novel polymer electrolytes and anode materials (see full report on p. 21).

Another Deakin team was awarded an AISRF grant in 2017. The team led by Prof Matthew Barnett and Dr Daniel Fabijanic received $1M for a project on 'Advanced manufacturing of new high entropy alloys'. The project addresses the global demand for new, high-performing materials, driven by demand for improved performance efficiencies and will pioneer new high-entropy alloy components and compositions using advanced manufacturing. High entropy alloys are a new class of alloys with outstanding potential for providing enhanced durability and energy reductions in energy, aerospace and mining applications. However, manufacturing these alloys in large and complex components is a challenge.

The team is co-led by Professor Budaraju Srinivasa Murty from the Indian Institute of Technology Madras.

The Australian team includes Professor Peter Hodgson and Professor Svetha Venkatesh as well as collaborators from RMIT (Professor Qian Ma) and Monash Universities (Professor Xinhua Wu). Indian partners are the Indian Institute of Technology Madras, the Indian Institute of Science Bangalore and General Electric India.

Europe

Strengthening connections with Spain

In 2017, IFM Associate Director, Professor Maria Forsyth, spent four months on sabbatical leave in the Basque region of Spain. She was based at POLYMAT in the University of the Basque Country working with Professor David Mecerreyes and his innovative polymers group in the area of polymer electrolytes for battery applications.

The group has close synergies with IFM's electromaterials group in their research on polymer electrolytes for battery applications.

Prof Forsyth also strengthened ties with other collaborators in the region – the CIC EnergiGUNE on sodium battery polymer electrolytes and Tecnalia, with whom Deakin has an MoU and many complementary research programs in areas such as membranes for gas separation and water purification, ionic liquids and electrochemistry, energy storage and corrosion.

Above: *Electromaterials group researchers meet up in San Sebastian. From L: Dr Andrew Basile; former IFM student, Jenny Yan; Dr Matthias Hilder; Prof Maria Forsyth; A/Prof Patrick Howlett and IFM/Technalia PhD student Laura Sanchez Cupido.*

Below: *Members of the AISRF team (Australian and Indian researchers) during the Australian-Indian Workshop for Women in Energy Research, 8 November 2017.*

Our Vision

To lead and inspire innovations in materials science and engineering that have a transformational benefit to society.

Our Mission

To create and translate knowledge at the frontier of materials science for globally raised standards of living via:

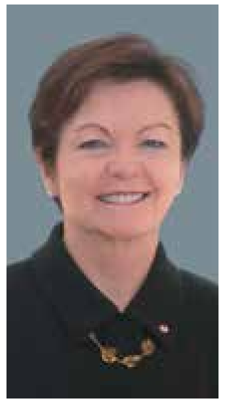
- innovations in manufacturing
- advanced biological and nature-inspired materials
- extraordinary material functionality
- breakthroughs in energy storage
- materials with tailored and regenerative lifetimes

through excellence in interdisciplinary research, training and engagement.

2017

Board Members

The IFM Board is responsible for the governance and oversight of the research, development and commercialisation activities of IFM.

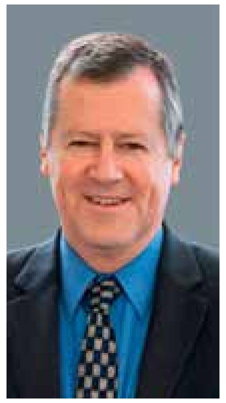


Professor
Jane den Hollander

Vice-Chancellor, Deakin University

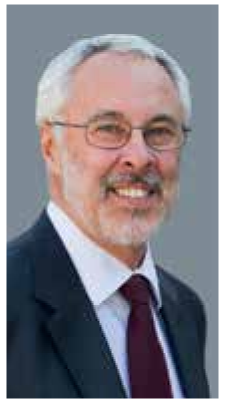
Professor
Peter Hodgson

Chair and Deputy Vice-Chancellor Research



Professor
Brendan Crotty

Executive Dean, Faculty of Health



Professor
Trevor Day

Executive Dean, Faculty of Science Engineering & Built Environment

Professor
Xungai Wang

Director, Institute for Frontier Materials (until 30 Nov 2017)

Professor
Maria Forsyth

Associate Director, Institute for Frontier Materials

Professor
Gordon Wallace

External Independent Director

Dr Leonie
Walsh

External Independent Director

Mr David
Marino

External Independent Director

Mr Derek
Buckmaster

Director, Carbon Nexus

Dr Ben Spincer

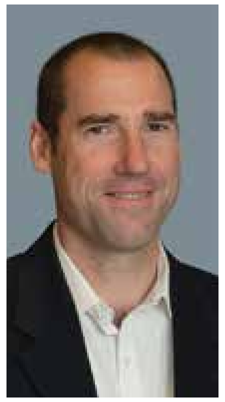
Director, Deakin Research Commercial

2017 IFM

Executive Team

Professor Xungai Wang
Director, Institute for Frontier Materials (until Nov 30)

Professor Maria Forsyth
Associate Director, Institute for Frontier Materials

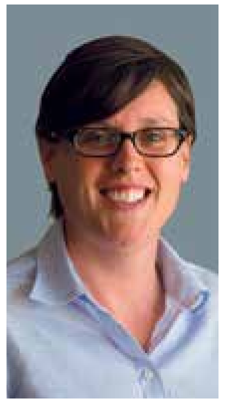


Professor Matthew Barnett
Interim Director, Institute for Frontier Materials (from Dec 1)

Professor Peter Hodgson
Deputy Vice-Chancellor Research

Professor Lingxue Kong
Professor, Research

Professor Russell Varley
Professor, Composite Materials



Professor Tiffany Walsh
Professor, Bionanotechnology

Mr Derek Buckmaster
Director, Carbon Nexus

Ms Virginie Hoareau
General Manager, Institute for Frontier Materials

Mrs Darlene Barnett
Senior Manager, Technical and Academic Support, Institute for Frontier Materials

Research Highlights

Innovations in materials science with real-world applications

Wet spinning line adds missing link

Carbon Nexus has increased its research and production capabilities with the installation of the only polyacrylonitrile (PAN) precursor wet spinning line in the Southern Hemisphere.

Jointly owned and operated by Carbon Nexus and CSIRO, the wet spinning line completes Carbon Nexus' value chain, allowing it to offer R&D services from precursor development to white fibre spinning, to carbon fibre production and composite manufacturing.

"With the installation of the wet spinning line and the 3D printers, our capability to conduct research across all the stages of carbon fibre production is enhanced beyond our current bench-top capabilities," said Professor of Composite Materials, Russell Varley.

The wet spinning line was custom built by an Italian company with input from Deakin and CSIRO researchers. The company liked the design so much it made another for its own factory and the the CSIRO/ Deakin machine has been described as "the Ferrari of wet spinning lines".

Assistant Minister for Industry, Innovation and Science the Honourable Craig Laundy MP officially launched the facility.

Future of carbon fibre is here

Deakin University and LeMond Composites have joined forces in a $58M deal to revolutionise the use of carbon fibre. The partnership, signed in June, allows LeMond Composites to license new technology developed at Carbon Nexus.

The technology, developed by IFM PhD student Maxime Maghe and former Carbon Nexus general manager Steve Atkiss, has potential to reduce the energy used in carbon fibre production by 75 per cent and reduces the process time from about 80 minutes to less than 15 minutes.

As well, the specialised machinery required is expected to cost about half the price of current equipment. The smaller equipment footprint makes possible a 70 per cent reduction in the size of a carbon fibre processing plant.

CEO of LeMond Composites, Greg LeMond said the ability to scale-up low-cost carbon fibre production had been the biggest hurdle to making the material widely available but the technology invented at Carbon Nexus would change this.

"Deakin University's manufacturing process will make it possible to localise manufacturing and make carbon fibre technology more accessible to a wider range of industries like transportation, renewable energy and infrastructure, or any industry that benefits from using lighter, stronger, safer materials," he said.

Below: *The Carbon Nexus technical team, from left: Gagandeep Dhillon; Alejandro Borda Coca; LeMond Composites CEO, Greg LeMond; Maxime Maghe, Deakin Vice-Chancellor, Prof Jane den Hollander, Chris Stones, Rohit Rana and Evan Llewellyn.*

3D roll forming facility: low volume parts and prototyping

A new $1.5 million facility installed at IFM in 2017 enables for the first time the roll forming of metal components that combine variations in width and depth over the length of the part.

The need for weight reduction in transport has led to the development of new, high performance materials such as Ultra High Strength Steels (UHSS), advanced aluminium alloys and metal laminates.

These new materials often show very limited ductility* and cannot be formed with conventional methods such as cold stamping. Extensive research performed at IFM has revealed the potential of the roll forming process for the forming of metal alloys that combine ultra-high strength and limited ductility.

In roll forming, metal strips are incrementally bent in successive roll stands, allowing high forming limits to be achieved. Roll forming of structural and crash components from UHSS is now widely applied in the automotive industry.

Conventional roll forming is limited to long sections of continuous profile. IFM's long-term research partner data M Sheet Metal Solutions (Germany) has recently developed the flexible roll forming process where the roll stands are no longer fixed in space but allowed to follow a part contour to manufacture components with variable shape along the length. The process enables the forming of high strength/low ductility materials with higher component complexity compared to conventional roll forming.

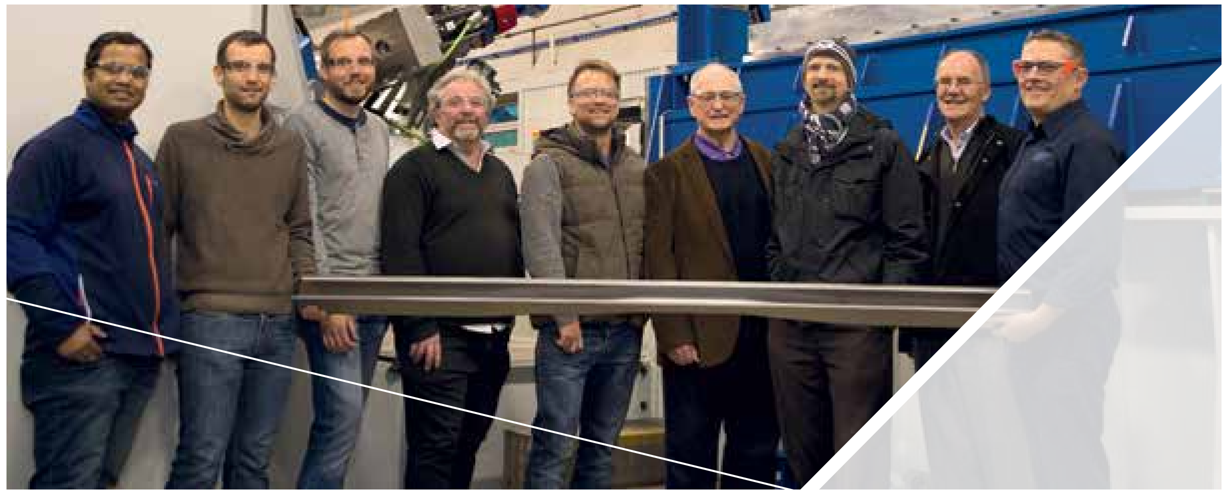
In collaboration with data M Sheet Metal Solutions, and supported by a recent ARC LIEF grant, IFM has established the next generation 3D roll former.

This one of a kind $1.5 million forming-facility enables for the first time the roll forming of components that combine variations in width and depth over the length of the part.

This world`s first 3D roll forming facility will be used for proof of concept studies on the flexible roll forming process, rapid prototyping and the low volume manufacture of complex profiles from hard to form materials for applications in the automotive, aerospace, truck and rail sectors.

Ductility is when a solid material stretches under tensile stress. If ductile, a material may be stretched into a wire.

Below: *Dr Buddhika Abeyrathna, Mr Johann Harrasser, Mr Matthias Wimmer, Prof Peter Hodgson, Dr Matthias Weiss, Mr Noel Miller, Mr Richard Taube, Mr Sam Davis and Mr Wayne Allen.*



Wellcome news for ear membrane project

Professor Xungai Wang, Dr Rangam Rajkhowa and Dr Ben Allardyce, together with their industry partner the Ear Science Institute Australia received a major grant from the UK Wellcome Trust.

The grant, worth $3.7M over three years will take the silk based membrane materials for perforated eardrum repair developed at Deakin to the clinical trial stage.

The silk membrane materials have been developed at IFM with support of an ARC Linkage Project and the ARC Research Hub for Future Fibres. Drs Rajkhowa and Allardyce will finalise the development and specifications of the silk membrane implants and supervise manufacture of the devices to be used in the clinical trials.

The silk membranes have a number of favourable properties – they are thin and able to vibrate like the natural eardrum, biocompatible, strong enough to resist inner ear pressure, they biodegrade when the eardrum is regenerated, and are easy to shape and manipulate during surgery. Now, the clinical trials will demonstrate how the membranes behave in the environment of the middle ear.

Below: *Dr Rangam Rajkhowa and Dr Ben Allardyce have developed the silk-based membranes which they hope will repair perforated eardrums.*

Plasma treatment extends milk shelf life

A breakthrough by IFM researcher Dr Sri Balaji Ponraj has shown that plasma treatment can extend milk shelf life by more than five weeks. The process could provide an alternative to pasteurisation.

Dr Ponraj said the plasma milk treatment method he and Dr Jane Dai pioneered with IFM senior research fellow Dr Julie Sharp is less aggressive than traditional pasteurisation, meaning the milk would not only last longer, but would maintain more of its nutritional value.

"We use a needle to send tiny gas bubbles through the milk, which can then be converted into plasma that provides an environmentally friendly, non-thermal approach to decontamination," he said.

"Using this method, the shelf life of milk can be pushed out to six weeks minimum, which could absolutely change the landscape of the bovine dairy industry."

Dr Ponraj began working on the project as a PhD student at IFM. The technique developed by the team injects argon gas into milk which is then energised between two electrodes immersed in the milk.

'Our results have shown that macronutrients like proteins, lipids (and fatty acids) and carbohydrates in milk were significantly retained after plasma treatment,' Dr Ponraj said.

'We've also found that micronutrients were significantly better in milk treated by plasma. These results show that plasma treated milk represents good milk quality.'

Dr Ponraj said the method could also have implications for the supply of human breast milk, by not only ensuring supplies in hospital wards and nurseries would last longer, but allowing the expressed milk to retain its vital nutritional benefits.

They are now working on scaling up the plasma decontamination method, which has attracted great interest from the dairy industry and also has potential for decontaminating other liquids such as fruit juices and water.

Above: *Dr Sri Balaji Ponraj and Dr Julie Sharp – plasma treatment extends milk shelf life and maintains nutritional value.*

Tiny gas bubbles are injected into the milk and converted to plasma – decontaminating milk while maintaining vital biological activity.

New fibres show strain-sensing ability

IFM researchers have achieved a new benchmark for high-performance multi-functional fibre fabrication using a new wet-spinning line.

Dr. Shayan Seyedin and PhD student Sepehr Moradi have fabricated a new class of fibres with strain sensing properties. This work, which was funded by an IFM impact grant with mentorship of A/Prof Joselito Razal, is the first to achieve smart functional fibres at a scale suitable for textile processing.

Dr Seyedin says the fibres produced are not only stretchable but also conduct electricity. This unique combination of properties allows the fibres to respond to any type of deformation, such as stretching or bending, by changing their electrical response.

The sensor fibres are made from polymer-based materials, i.e. polyurethane and an organic electronic conductor, and so will have the feel of a fabric once they are knitted or woven into clothing. The researchers have fabricated these smart fibres based on the technology previously established in their group.

The access to the new wet-spinning line enabled them to scale-up the fabrication and to achieve fibres with higher electrical conductivities and sensing capabilities. The team's next target is to knit the sensor fibres into textiles and use them for body movement measurements.

New smart fibres are stretchable and can conduct electricity

Above: *Dr Shayan Seyedin (right) has developed strain sensing textile fibres to create clothing that keeps track of the wearer's movements.*

Extraordinary Material Functionality

IFM researchers achieve boron nitride nanotube breakthrough

IFM researchers have achieved a world-first in successfully 3D printing a Boron Nitride Nanotube/Titanium composite.

The breakthrough has significant implications for industries such as aerospace, defence, automotive, energy and health.

Leader of IFM's Nanotechnology Group, Prof Ian Chen said that Boron Nitride Nanotubes (BNNTs) are an advanced new nanomaterial with many unique properties.

"They are ultralight, super strong and incredibly resistant to heat".

However, in the 20 years since the material's discovery, it has only been possible to produce it in small amounts. This has seriously limited its practical use in product development.

"Our novel and scalable manufacturing process can effectively eliminate this production bottleneck and unleash the real power of BNNTs into the marketplace," said Prof Chen.

The successful demonstration of BNNT 3D printing is the result of a collaboration between Prof Chen's group and the additive manufacturing team, led by Dr Daniel Fabijanic.

While BNNTs have a structure similar to carbon nanotubes and share the same extraordinary mechanical properties and thermal conductivity, they are able to withstand double the temperatures (up to 800°C).

This superior heat tolerance is critical for surviving the extreme temperatures involved in melting and liquefying powders during the 3D printing process for metal matrix composites.

BNNTs also have greater chemical stability and electrical insulation properties, the ability to shield against neutron and ultraviolet radiation and to generate electrical current when subjected to mechanical stress.

Unlike carbon nanotubes, they can be fashioned into transparent materials like windscreens, or dyed different colours.

"When integrated into composite materials and systems, BNNTs enable entirely new classes of material performance across many industrial applications," Prof Chen said.

Potential applications could include metallic, polymer and ceramic composites and transparent materials for the defence and the automotive sector; thermally conductive and electrically insulating material for the semiconductor industry and sensors and structural or multifunctional applications for the aerospace and energy sectors.

BNNTs also have potential for use in batteries, supercapacitors and hydrogen storage devices for energy storage, fire retardant construction materials for the construction sector and cancer and cellular regeneration therapies.

According to Prof Chen, only three organisations globally claim to be able to produce BNNTs in relatively large volume at scale.

However, the process is costly and energy intensive, which may make it difficult to sustain for large scale industrial manufacturing.

"In contrast, the IFM technology promises to offer the highest production rate as well as being more energy efficient and industry friendly, as it is based on current industry equipment," Prof Chen said.

The new technology has been patented ready for scale up to meet the increasing demand for BNNTs and plans to build a commercial BNNT pilot plant on the Geelong Waurn Ponds Campus to produce BNNTs in kilogram quantities.

Above: *3D printed boron nitride nanotube/titanium composite.*

Filter uses solar rays to help reduce pollution

Volatile organic compounds (VOCs) from chemical manufacturing processes are contaminants in air and precursor pollutants for the formation of fine particulate matter.

Following a successful pilot study of a new technology developed by IFM, the Victorian-Jiangsu Program for Technology and Innovation supported Jiangsu BOHN Environmental Protection Science and Technology Co Ltd and Deakin University with a new project in 2017. This project aims to evaluate the commercial potential of the technology.

The technology uses a graphene-based photocatalytic metal foam as an active filter to treat VOCs. In the pilot study it significantly improved the breakdown of VOCs – up to 12 times the rate of the commercially available photocatalyst.

Dr Jinfeng Wang

IFM researchers Dr Jinfeng Wang and Dr Jing Wang are working on a long-term, on-site performance trial and pilot-scale production of the active filter, which will be ready for practical use. The successful completion of this collaboration has potential to provide an environmentally friendly method for treatment of VOCs, thus enabling the long-term sustainability of chemical manufacturing.

New materials for large-scale, high-performance batteries

Efficient energy storage is the missing link that will allow the world to reduce its dependence on fossil fuels and move towards a reliable energy supply that includes renewable resources.

A project supported by the Australia India Strategic Research Fund (AISRF) is demonstrating new lithium and sodium prototypes based around the development of new materials. This work will help realise the goal of low-temperature, high-stability lithium and sodium-based energy storage technologies.

In 2017, the team successfully developed large-scale polymer electrolytes and assembled the first all-solid-state pouch cell, using the novel solid polymer electrolytes, one of the key targets for this project. For the high-energy-density batteries that include lithium-sulphur, sodium-air batteries are also under investigation.

Effective collaboration is leading to great outputs for the project. Besides the regular video meetings with our Indian collaborators, researchers' visits and face-to-face meetings are essential for maintaining strong links. In October 2017, Dr Gaetan Girard, a research fellow in IFM's electromaterials group visited IIT Mumbai and IISc Bangalore, where he successfully applied the developed polymer electrolyte with novel anode materials. The results showed excellent electrolyte/electrode compatibility and outstanding performance, which is a major breakthrough for the project.

In November 2017, the Deakin team organised a workshop for Women in Energy Research in Melbourne. More than 30 researchers from University of Delhi, Advanced Research Centre International for powder metallurgy and New Materials-Chennai, Institute of Science (IISC)- Bangalore; and Australian universities (Monash University, RMIT University, Deakin University) attended, helping to increase understanding about Australian and Indian cultures and also strengthening the partnership. Deakin PhD student Urbi Pal visited IIT Mumbai and IISc Bangalore, where she helped test novel liquid electrolytes against novel sulphur cathodes. Other visits have been planned for 2018 to continue the work. Some results have been published and others submitted to high impact journals.

The discoveries from the project have also attracted the attention of industry, with some potential industry partners expressing interest in the materials and devices developed. Their engagement will accelerate the prototyping process, which is the main target of the project in the final year.

Below: *Members of the AISRF team (Australian and Indian researchers) in front of the Royal Exhibition Building during the Australian-Indian Workshop for Women in Energy Research, in Melbourne.*

Batteries to power prosthetic limbs breakthrough

A team of IFM researchers is working on ways to power the next generation in prosthetic limbs.

Scientists from the Battery Technology Research and Innovation Hub (BatTRI-Hub) are aiming to develop safe and reliable batteries for a unique robotic hand created by researchers from the University of Wollongong as part of the ARC Centre of Excellence for Electromaterials Science (ACES).

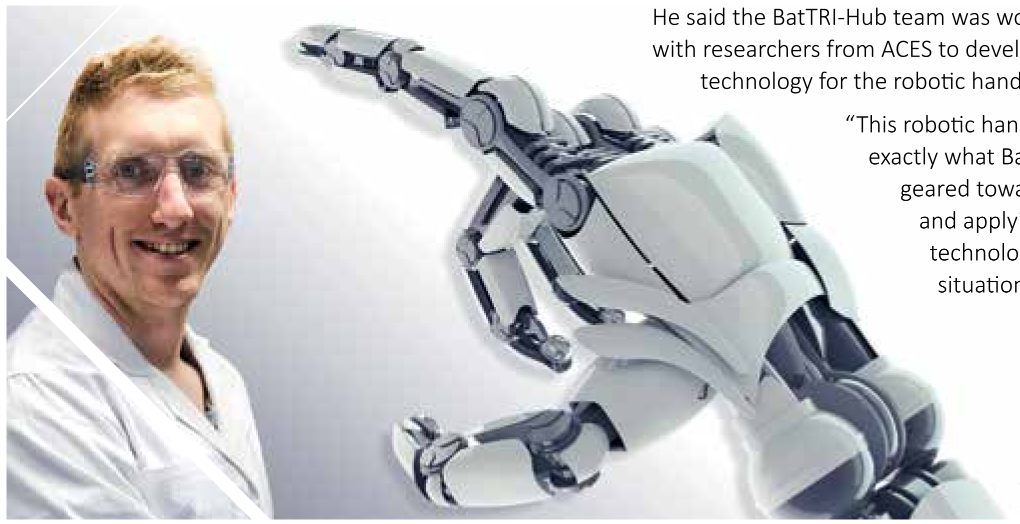
The soft robotic hand prototype, unveiled in 2017, combines new, intelligent materials with 3D printing techniques and responds to neural commands like a real limb, allowing the user to make life-like movements.

The team at BatTRI-Hub have developed a lithium metal device that is capable of powering one finger of the hand and are now working through the simultaneous challenges of devising a uniquely shaped battery that is powerful enough to run the whole hand and also incorporates next-generation materials.

"Our researchers have carried out extensive work using ionic liquids, which are a pure salt with a chemical composition that allows them to be liquid at room temperature," explained IFM's Dr Robert Kerr.

"What's great about these materials is that they are completely non-volatile and are really difficult to ignite – unlike the lithium ion cell used in current battery technology – which makes them a safer alternative for this kind of application."

However, the challenge in using ionic liquids is to achieve the same level of performance as a normal lithium ion cell.



"Moving into the beyond lithium ion space, the goal is to increase the charge capacity of the battery by using high capacity electrodes. In our approach to using lithium metal, we know that controlling the surface of the lithium metal, or the solid/electrolyte interphase, is critical.

"It actually comes down to the choice of electrolyte used in the cell and the way it reacts with the lithium metal electrode. To build on the stability of ionic liquids we can incorporate them into solid electrolyte systems to form a mechanical barrier," Dr Kerr said.

The team's work has led to the development of a lithium metal pouch cell containing an ionic liquid-based electrolyte. The components of the battery are layered inside the pouch, rather than rolled up into a cylinder like a normal battery, allowing them to pack more efficiently and use lighter casing materials.

"One small single-layered pouch can power the robotic finger, and if we start to stack them we can achieve 25 electrode pairs, which is about the capacity of a quarter of a phone battery," Dr Kerr explained.

The result, however, is bulky and inflexible, leading to the next challenge with powering the whole robotic hand.

"One of the issues we're exploring is how to create conformable batteries that we can tailor to the shape of the hand or arm. We also need to consider how the battery is attached to the limb and how to make it easily accessible for recharging," Dr Kerr explained.

He said the BatTRI-Hub team was working closely with researchers from ACES to develop the battery technology for the robotic hand.

"This robotic hand project is exactly what BatTRI-Hub is geared towards – prototyping and applying our battery technology to real-life situations," Dr Kerr said.

***Left:** Dr Rob Kerr and the robotic hand prototype.*

Global award for green denim team

An IFM team, led by Professor Xungai Wang, won the H&M Foundation's Global Change Award, for their idea to recycle denim by turning used denim into ultrafine particles, and then coating or printing the colour particles onto undyed new denim.

The team, which includes Drs Rangam Rajkhowa, Nolene Byrne, Christopher Hurren and Rebecca Van Amber, travelled to Stockholm, Sweden to receive the €150,000 award.

On average, the life cycle of a pair of denim jeans produces more than 30 kg of CO_2 and uses around 3,500 litres of water. Dr Rangam Rajkhowa said IFM's Circular Denim project would address the key issues in denim production, and was likely to significantly cut the water and energy consumption, while creating new fashion effects for denim.

"This way, the old denim is reused, and new denim does not have to be dyed using the traditional yarn dyeing approach which consumes a huge amount of water and energy," he said.

"If necessary, the colour of the fine particles can be enhanced or changed easily before the coating or printing process. This will also help create a new fashion effect for denim products.

"Our previous work shows that fibre particles can take up dye under room temperature within five minutes due to very high surface area, hence significantly reducing the energy used to heat water under conventional dyeing process," he said.

Following the award, the team developed the technology, and were able to showcase the 'denim dyed denim' applied to jeans dyed using the pigment from old, recycled jeans.

"If even a small percentage of jeans are dyed using our new technique, the amount of water saved would have a significant impact on the environment," said Professor Xungai Wang.

***Above:** Dr Rebecca Van Amber with pigment made from recycled denim jeans.*

Setting the standards for protective motorcycle gear

After many years of work behind the scenes, Dr Christopher Hurren, Dr Liz de Rome and colleagues have successfully secured the tender with Transport for New South Wales to carry out the first year of testing for a star rating system for motorcycle protective clothing for Australia and New Zealand.

The program will covertly buy 10 per cent of motorcycle clothing available in Australian and New Zealand stores. This clothing will be tested for its protection and thermal comfort and the rating will be available on a website to help riders make informed decisions about the protective clothing they buy.

The first year is a transition year where testing will be conducted to benchmark the performance of garments in the current market. Those test results are not for publication but will be provided confidentially to the responsible manufacturers and licensed importers to demonstrate how their garments would be rated under the new system and to allow them time to modify their stock if necessary. The tender is worth $514,000 for the first year.

Below: *Motorcyclists gathered at IFM for a seminar to discuss the issues around improving motorcycle safety.*

Solid-state NMR unlocks amber time capsules

An analysis of fossilised tree resin using Deakin's nuclear magnetic resonance (NMR) facility has revealed the unique chemical structure of each piece of amber.

Working with Monash University researchers, IFM's Dr Luke O'Dell used solid-state 13C NMR to investigate the make-up of 50-million-year-old amber samples recovered from sites in Anglesea, Victoria, and Strahan, Tasmania.

Dr O'Dell said the amber captured a period in time during the Eocene Epoch (56 to 33.9 million years ago) and was "an unparalleled method of preservation, providing insights into past organisms, ecosystems and environments".

The collaboration aimed to identify the original plant sources of amber at Anglesea and Strahan and to establish the way they degraded during their tens of millions of years underground.

This degradation could potentially have a major impact on the preserved palaeobiological information contained within the samples, and the sort of information that can be recovered about Earth's ancient past.

Above: *Dr Luke O'Dell, investigates some ground amber ready for NMR analysis.*

The NMR experiments were carried out at IFM's NMR facility using the Bruker 300 MHz Avance III spectrometer and 'magic angle spinning' probe. The spectra provided detailed information on the chemical constituents of the amber, allowing the identification of distinct botanical sources.

The Monash team conducted their own chemical analysis using reflective and infrared spectroscopy.

Study lead author, Monash School of Earth, Atmosphere and Environment Honours student Andrew Coward, said the project could represent the first unambiguous discovery of indigenous Class II amber in Australia.

"NMR turned out to be extremely useful as it provided us with a unique fingerprint of the chemical structure of each piece of amber," Mr Coward said.

"Amber can be separated into different classes based on which plants it came from, and our discovery of Class II amber from the Anglesea site could mean certain prehistoric plants capable of producing cardinene-based amber were native to Australia during the Eocene period, which is something that has never been proven due to their absence from the fossil record".

Reference: Coward, A. J., Mays, C., Patti, A. F., Stilwell, J. D., O'Dell, L. A., & Viegas, P. (2018). Taphonomy and chemotaxonomy of Eocene amber from southeastern Australia. Organic Geochemistry, 118, 103-115. DOI: 10.1016/j.orggeochem.2017.12.004

Collaborative Centres

ARC Research Hub for FUTURE FIBRES

ARC Research Hub for Future Fibres

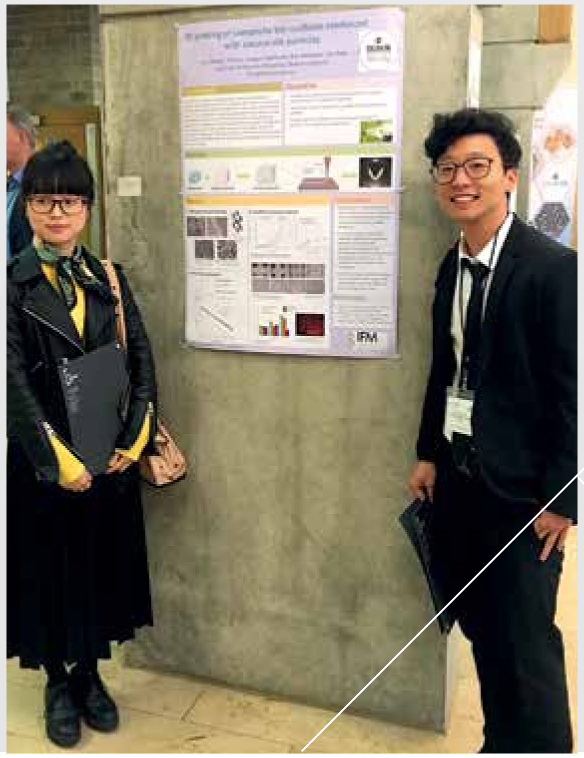
The Hub made many significant achievements in 2017. From filing multiple patents to publishing 14 high quality journal articles, our research has had a visible impact on industry and the academic community.

Highlights

Three provisional patents were filed by Hub research teams:

- Development of single layer protective denim (with Draggin Jeans)
- Novel processes for treating fabrics with short polymer fibre technology (with HeiQ)
- New materials for use in carbon fibre automotive wheels (with Carbon Revolution).

All of these technologies are in the process of being adopted by the industry partner to release new products into the marketplace and drive growth and competitiveness within their sectors. Another seven new processes or products were identified as a result of Hub research. These are being adopted by industry partners or utilised within the Deakin team.



Research outputs include 14 journal articles, 14 invited lectures, and attendance at various conferences. The journal articles span topics from glycerol-plasticised silk membranes to tailoring carbon fibre-to-matrix interactions using surface modification. Hub members delivered invited lectures in Geelong, China, France, Greece and Egypt, to a variety of audiences from conference delegates to industry groups and university departments.

The Hub organised or sponsored five events in 2017.

- 1st Future Fibres Symposium, 27-28 February, Geelong
- Smart and Intelligent Textiles Conference, (co-sponsored by TTNA/Hub), 24 August, Geelong
- Hub researchers mini-conference, 18 October, Geelong
- 1st Motorcycle Safety Seminar and Workshop, (sponsored by Hub), 27 October, Geelong
- Future Fibres Strategy Workshop, 1 December, Geelong.

Students

Two PhD students started their projects, with another five due to start in 2018.

- Beini Zeng is working on the development of an up-cycling process for denim waste using ionic liquids
- Mina Battayork is working on the production of multi-functional silk particles by spray drying.

In addition, the Hub has had five visiting students, working on various projects from short polymer fibres through to silk membranes. These students have joined us from Switzerland, USA, France and Germany.

Left: *Hub associate member, PhD student, Ms Jun Zhang (L) working in the area of 3D bio-printing, received a poster award at the SELECTBIO – Bioprinting conference in Cambridge, UK.*

Grants and Awards

Hub members have had a very successful year, obtaining over $5 million in additional funding, and winning many awards. Some highlights are listed below:

- Fellow of the Australian Academy of Technology and Engineering (ATSE) – Bronwyn Fox
- Victorian Young Tall Poppy Science Award – Luke Henderson
- Three Deakin Vice-Chancellor's Awards:
  - Research Excellence by Mid-career Researcher – Joselito Razal
  - Industry Engagement in Research – Carbon Nexus team, including Luke Henderson
  - Outstanding Contribution though Innovation that spans the Value Promise – IFM/PRaDA team including Alessandra Sutti and Teo Slezak.

20 new
associate members

Media

Several Hub-related stories caught the media's attention in 2017. The award of the H&M Global Foundation grant for the Denim-dyed denim project created much media interest. Articles appeared in The Age/Sydney Morning Herald, the Geelong Advertiser, Huffington Post Australia and The Australian. Interviews were also aired on ABC Radio National Breakfast and 3RRR Einstein-a-go-go.

Similarly, the success of the silk ear membrane project receiving funding from the Wellcome Trust was also reported in print in the Geelong Advertiser, National Geographic, 9news.com.au and ABC News online. Members of the team were interviewed on The World Today (ABC radio), Bay FM and ABC News 24 (TV).

Associate members: In 2017 we introduced a new class of Hub membership to include other researchers, students or employees who are working in related areas, resulting in 20 new associate members.

Visitors

The Hub hosted more than 20 national and international academic visitors, including four of our international Partner Investigators, as well as researchers in carbon fibres, textile technology, silk materials and conductive fibres. Hub members also spread our research throughout the world, visiting 28 research groups, facilities or companies overseas. We also interacted with more than 50 industry visitors throughout the year, from a wide range of companies.

Above (left): *3D printing of silk/bio-scaffolds may potentially be used for cartilage tissue engineering.* ***(right)*** *IFM research engineer Dr Amol Patil inspects a sample undergoing a pilling test.*

mineALLOY

The ARC Training Centre in Alloy Innovation for Mining Efficiency (mineAlloy) officially began operations on 27 March 2017, after the signing of the partners' agreement, with a financial commitment of $4.8 million from ARC and $2.5 million from participating organisations over 5 years.

mineAlloy aims to train scientists and engineers in transforming Australia into a producer of world-class equipment and wear resistant components for the mining equipment, technology and services (METS) sector. Postgraduate students and researchers work on projects proposed by the industrial partners (Weir Minerals, Gekko Systems, Keech Castings, IXL Metal Castings, Trelleborg Engineering and CastBonding Australia) and under the supervision of experienced researchers at Deakin University, Monash University, University of Queensland and CSIRO. The centre also has valuable support from Austmine, METS Ignited, Materials Solutions Ltd, Newcrest Mining, the Australian Foundry Institute and the Central Institute of Technology at TAFE WA.

During 2017, the partners finalised the scope of the projects and the research organisations appointed students and staff to them. The whole mineAlloy team met for the first time on 26 August 2017 at Waurn Ponds Estate to discuss progress and future plans. Then mineAlloy was officially launched by the Minister for Education and Training, the Hon Simon Birmingham, on 8 November. This event coincided with the first meeting of the Advisory Board, which is comprised of representatives from industry, academia and industry bodies. Despite its short existence, the mineAlloy centre is already enhancing collaboration between universities and industry.

Highlights

In its first year of operation, the participating organisations started 11 collaborative research projects, with success stories across three research themes:

- **Alloy development:** mineAlloy researchers are exploring new alloy compositions for ground engaging tools, ore chute liners and rock crushers using advanced materials characterisation techniques at Deakin University, the Australian Synchrotron and OPAL reactor of ANSTO, revealing the structure of these alloys with extraordinarily high resolution.
- **Manufacturing innovations:** Both powder-bed and blown-powder 3D printing technologies are being used to manufacture cemented carbide components, with a high volume fraction of tungsten carbides and low porosity. The researchers are studying the microstructure, mechanical properties and wear resistance of these components.
- **Modelling and sensing wear:** Open source and commercial software packages are being used to improve component design and predict their performance and lifetime. At the same time, mineAlloy researchers have identified new concepts for smart alloys and wear sensing devices, with applications throughout the METS sector.

Finally, the mineAlloy training centre is committed to establishing a National Wear Testing Network, to facilitate materials selection based on highly calibrated wear tests. Several facilities across Australia are now available via our Wear Network, offering a wide range of equipment for researchers and industry partners to assess the wear behaviour of materials.

Left: *mineAlloy PhD student, Mr Guillaume Bruel, conducting an experiment at the Powder Diffraction line of the Australian Synchrotron.*

ARC Centre of Excellence for Electromaterials Science

ARC Centre of Excellence for Electromaterials Science (ACES)

Researchers in ACES continue to advance the discovery and development of electromaterials - materials that carry electrons/ions - and their integration into devices for energy, robotics, bionics and diagnostic applications.

Funded by $25 million from the Australian Research Council and running from 2014–2020, ACES now incorporates eight Australian collaborating organisations and five international partner institutions, having welcomed the University of NSW as a new Australian node in 2017.

Awards

Notable awards in 2017 include:

- ACES Associate Director, Prof Maria Forsyth, received the Victoria Prize for Science and Innovation in Physical Sciences
- ACES Director, Prof Gordon Wallace was appointed an Officer in the General Division of the Order of Australia (AO), and was named 2017's NSW Scientist of the Year
- ACES Chief Investigator, Prof Doug MacFarlane at Monash, a long-time collaborator of the electromaterials group at Deakin, was awarded the prestigious Australian Academy of Science 2018 David Craig Medal
- ACES Chief Investigator Prof Michelle Coote of ANU was awarded the ARC Georgina Sweet Australian Laureate Fellowship
- ACES Chief Investigator, Prof Mark Cook of the University of Melbourne was elected Fellow of the Australian Academy of Health and Medical Sciences
- The ACES team behind the "Biopen" invention were finalists in the Australian Museum Eureka Prizes.

Above: *MP for Broadmeadows, Mr Frank McGuire presents the Victoria Prize for Science and Innovation to Prof Maria Forsyth.*

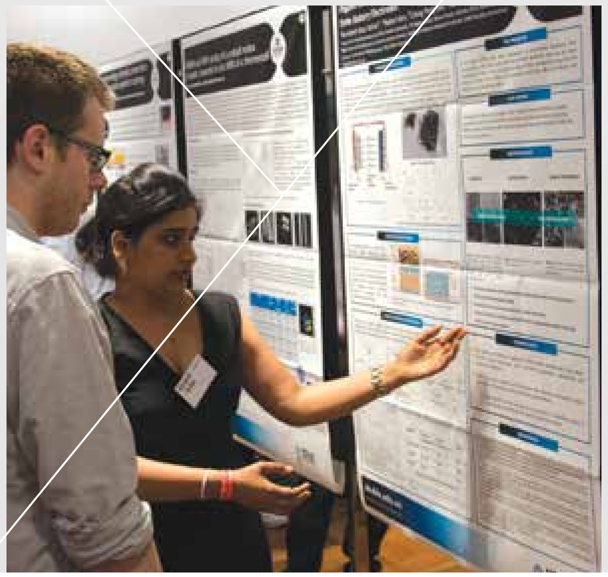
20 Papers published in 2017

Research Highlights

Batteries

Two battery technologies have primarily been explored in 2017 – high energy density redox-flow and sodium-oxygen devices. In both projects, ionic liquids (ILs) have been key electrolyte components. For redox-flow batteries, one focus has been on the development of zinc-based anodes employing high concentration electrolytes to enhance safety and energy density. For this research, 3D printed flow cell test reactors were designed and printed.

In the sodium-oxygen battery research, the focus was on developing understanding of the oxygen electrode processes in the IL electrolytes that support good cycling. A novel 3D printed electrochemical 'air' cell allowing high quality measurements and post cycling characterisation of electrodeposits was designed and tested and prototype coin-cell Na-oxygen devices were tested, incorporating ACES developed carbon air cathode materials and commercial electrodes.



Thermocells

Research into devices for harvesting low-grade waste heat – called thermocells – focused on two aspects, (i) exploration of new redox couples for use in IL electrolytes and (ii) strategies to develop quasi-solid state electrolytes and improve device designs. This research was reviewed as part of an invited perspective in *Chemical Communications*.

Modelling

Molecular dynamics (MD) simulations have been used to study the interfacial behaviour of two IL systems previously tested experimentally for application in zinc flow batteries. Modelling has also provided important insights into the oxygen reduction reaction in ionic liquids – a key process for metal air batteries – and also into the development of polymer electrolytes.

International Collaborations

Prof Maria Forsyth formed strong international connections during her nine months spent in Spain during 2017. Prof Forsyth was initially based at POLYMAT in the Universidad del País Vasco (The University of the Basque Country) in San Sebastian working with Prof David Mecerreyes' innovative polymers group. Prof Mecerreyes has previously visited IFM as a Deakin University Thinker in Residence, and Prof Forsyth's visit further strengthened this collaboration. Three papers were published with Prof Mecerreyes in 2017. ACES also signed an MoU with CIC energiGUNE, Spain, to facilitate further staff and student exchanges in the area of energy storage.

The IFM team in ACES published 20 papers and 1 book in 2017. Details are included in the supplement to this report.

Left: *MPhil student Karmjeet Buttar explains her poster to ACES Assoc Member, Dr Luke O'Dell.*

Energy Pipelines Cooperative Research Centre

The Energy Pipelines CRC (EPCRC) provides research and training to support Australia's energy pipeline industry.

Deakin University leads the EPCRC program on coatings and corrosion, which is headed by Professor Mike Yongjun Tan.

Highlights & New Developments

The Deakin Corrosion Research Centre's focus is on corrosion engineering and infrastructure durability studies. The centre's major research programs have a particular emphasis on the reliability, durability and protection of critical industrial infrastructure, such as energy pipeline infrastructure.

Major progress was made in developing a pipeline corrosion monitoring and prediction system, and in understanding corrosion and protection of complex industry structures, including shore-crossing and HDD pipelines. The National Facility for Pipeline Coating Assessment (NFPCA) provides research and development for the Australian pipeline industry.

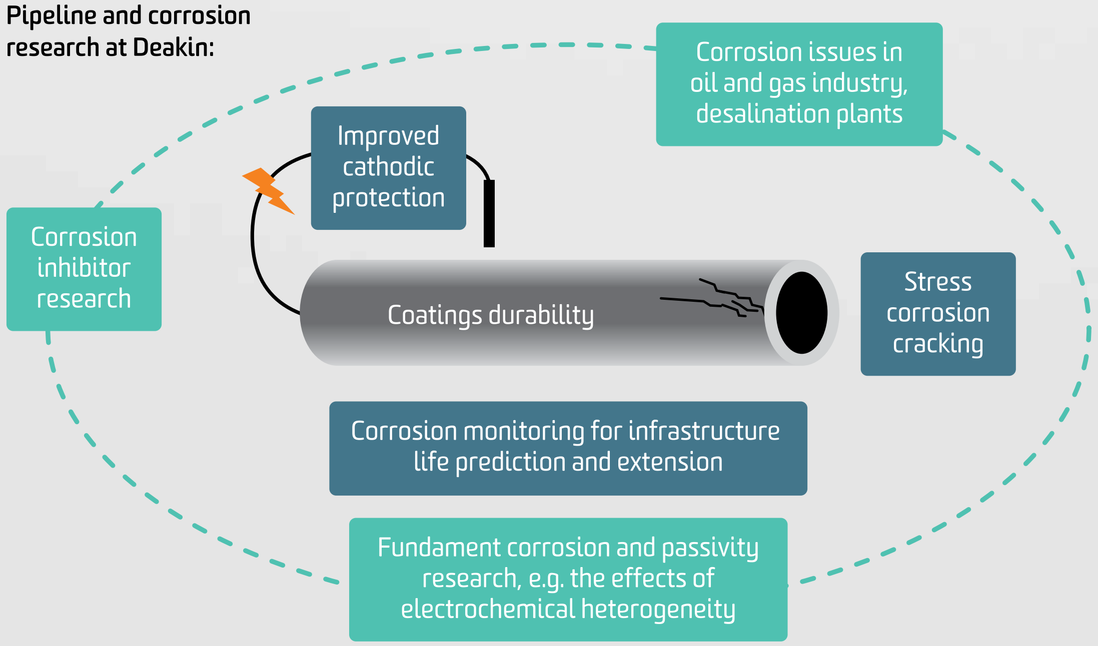
These initiatives are the result of active and fruitful collaborations between IFM and School of Engineering researchers.

Significant progress was made for all EPCRC research projects, with all milestones successfully achieved. Some 19 journal and major conference papers were prepared based on these projects in 2017.

Ten final year mechanical/civil engineering students have successfully carried out their final year projects in the new NFPCA and corrosion laboratory. All projects were directly linked with industry needs.

Targeted collaborations with energy pipeline, oil and gas and corrosion engineering industries continued in conjunction with major initiatives at the Australian Centre for Infrastructure Durability. Targeted international collaboration with Wuhan University of Science and Technology (WUST) in the areas of corrosion and pipeline research enhance Deakin's major international teaching and research collaboration initiatives.

Pipeline and corrosion research at Deakin:



Excellerate Australia

Excellerate Australia (formerly the AutoCRC) was funded until 2017 to implement the Auto 2020 roadmap for Australia.

The aim is to transform the Australian automotive industry from being an innovation follower to a technology provider for the Asian region in strategic areas.

IFM is the lead institute for the lightweighting theme in Excellerate Australia's sustainable manufacturing research area.

Above: *Carbon fibre composite seat back structure.*
Below: *Cars coming off production line.*

Highlights

Development of a low-cost composite front seat back

This project was an extension of a previous AutoCRC project, where Carbon Nexus, together with Australian components manufacturer, Futuris, successfully produced a two-piece carbon fibre composite front seat back. The new seat back achieved a 69% mass reduction compared to the current steel seat frame due to its integrated part design.

Along with improved performance, the composite front seat back enables improved styling and design freedom that enhances aesthetic appeal and comfort. However, the cost of the composite seat back was relatively high due to material costs and its current manufacturing approach.

The continued development of the project focused on reducing costs through materials and component design that also enables higher production volumes. Using a multi-material approach for the inner and outer seat structure, a low-cost composite seat back that could be realistically considered for commercial application was developed and the following achieved:

- Successfully produced two-piece prototype seat structures
- 30% reduction in seat cost compared to previously developed carbon fibre composite front seat back
- 54% weight reduction over current metal frame seat.

Carbon Nexus

Since commencing operations in 2014 the Carbon Nexus research facility at IFM has established itself as a world-leading centre for research into carbon fibre processing and carbon composite materials.

Highlights

- Together with CSIRO commissioned a PAN precursor wet spinning line - a $1.6 million investment to enable the development of innovative precursor fibre recipes and processes
- A new lab-scale carbonisation process research tool, the Carbonisation Simulator, developed by Furnace Engineering was installed
- Re-certification of our Quality Management System to the upgraded standard ISO:9001-2015 was successfully completed
- More than 200 delegates attended the 4th Bi-Annual Carbon Fibre Futures Conference, held at The Pier on the Geelong waterfront. The attendees represented universities, research centres and companies from around the world
- A memorandum of understanding was signed with KC Tech and KI Tech of Korea for joint research programs into carbon fibre processing and materials.

Awards

- Carbon Nexus won the Innovation, Research and Development Award at the Geelong Business Excellence Awards in August
- A team of Carbon Nexus technicians and researchers received the 2017 Vice Chancellor's Award for Industry Engagement in Research.

In June, Deakin University signed a major licence agreement with LeMond Composites for technology enabling a significant reduction in the manufacturing cost of carbon fibre materials. LeMond Composites announced their intention to put this technology into use in their new carbon fibre manufacturing plants, soon to be constructed in Geelong and Tennessee, USA.

Building on the technology agreement, LeMond Composites received two significant grants, one under the Regional Jobs and Infrastructure Program and one under the Advanced Manufacturing Growth Fund, towards the construction of their full-scale carbon fibre manufacturing plant in Geelong.

***Below:** PhD student, Kathleen Beggs working on the carbon fibre line.*

Battery Technology Research and Innovation Hub (BatTRI-Hub)

The BatTRI-Hub is a research and innovation centre focused on advanced battery prototyping and the commercialisation of energy storage technologies.

The centre builds on IFM's expertise in key energy technologies and advanced polymer materials. BatTRI-Hub projects are centred around the development of advanced electrolytes based on the following classes of materials:

- ionic liquids
- plastic crystal composites
- polymer composites.

In 2017, the BatTRI-Hub supported 10 PhD projects and four postdoctoral research fellows working with industry partners. We have tested silicon electrode materials for one partner and we have established a local supplier of electrolyte materials.

Research Highlights

- **Custom cell geometries for niche applications (the ACES hand):** The ability to design cells of unique geometry may have applications where space is extremely limited or not suited to standard geometries. We are designing tools to assemble curved batteries for the ACES soft robotic hand.
- **Metal electrode preparation:** The preparation of thin lithium and sodium metal electrodes has started with the new rolling press. This is a unique capability for any battery prototyping facility.
- **Testing capabilities expanded:** A further 64 channels are being installed, bringing the total to 128 oven-enclosed channels. A new rack of 15A per channel raises the capability to 120A pack testing.
- **Automated stacking unit:** In conjunction with IISRI and a local company (Sensorplex), we have started the design and construction of a robotic multi-layer stacking unit that will have capabilities unique to any facility in the world. The robot stacker will automate a high precision process needed to fabricate advanced solid state high energy batteries.
- **QUT collaboration:** Our two research engineers visited the Queensland University of Technology cylindrical cell prototyping facility to initiate a collaborative materials exchange. They prepared electrolytes for our cells.
- **Solid state electrolytes:** PILBLOC electrolytes/binder systems have recently shown extremely promising performances. CSIRO has successfully scaled up the production of PILBLOC materials. Methods of incorporation into pouch cells are now underway. A hot press is being delivered for pouch cell prototyping.

***Above:** Visitors to BatTRI-Hub at the IFM Industry Day.*

Australian Centre for Infrastructure Durability

Making connections

The Australian Centre for Infrastructure Durability (ACID) connects industry with Australia's leading researchers and facilities for infrastructure durability to develop new solutions, technology and educational programs for:

- Smarter maintenance through advanced health monitoring/predictive models
- Enhanced mitigation of deterioration
- Advanced materials to maximise the life of new infrastructure.

In 2017 ACID researchers completed an ARC Discovery grant that analysed the transport of corrosive chloride through concrete.

Work is underway on developing very strong concrete using carbon nanotubes, supported by an ARC Linkage grant. The outcomes to date have been very promising. In another project, ACID researchers are developing a wireless sensor that is embedded in concrete and detects corrosive chloride ingress with depth to the steel reinforcement.

ACID's Research Partners include Universities (Deakin University, University of Sydney, Swinburne University, Curtin University, RMIT University, University of NSW, Queensland University of Technology) plus two Research Organisations (ANSTO and CSIRO).

AUSTRALIAN CENTRE FOR
INFRASTRUCTURE
DURABILITY

Industry Partners

Australia

Advanced Metallurgical Solutions Pty Ltd
AECOM
ALS Global Pty Ltd
AMOG Engineering
Anti Corrosion Technology
ArcActive Ltd
Atteris
AusComposites Manufacturing Facility
Austmine Ltd
Austral Services Group
Australia Defence Apparel
Australian Foundry Institute
Australian National Fabrication Facility
Australian Pipeline Industry Association
Australian Roll Forming Manufacturers (ARM)
Australian Wool Innovation Ltd
Australian Wool Testing Authority (AWTA)
APA Group
Backwell IXL
BHP Billiton
Bluescope Steel Pty Ltd
Callidus Welding Solutions
Capral Ltd
Carbon Revolution Pty Ltd
Carpenter Technology Corporation
Cast Bonding Australia Pty Ltd
Charles Parsons Pty Ltd
CleanTeq Ltd
Conflux
Cotton Research and Development Corporation
CPE Systems Pty Ltd
CSL Ltd
Cytomatrix Pty Ltd
Defab
Defence Materials Technology Centre
Defence Science Technology Group
Delaminating Resources Pty Ltd
Denso (Australia) Pty Ltd
Draggin Jeans Pty Ltd
Ear Science Institute Australia Incorporated
Eco2000 Pty Ltd
Eden Energy Ltd
ELG Carbon Fibre
Energy Pipelines CRC
EP Robinson Pty Ltd
Excellerate Australia (formerly AutoCRC)
FMP Bendix
Ford Motor Company
Futuris Pty Ltd
Gale Pacific Ltd
Galvanisers Association Australia
Geelong Abrasive Blasting
Geelong Textiles Pty Ltd
Gekko Systems Pty Ltd
Geofabrics Australasia Pty Ltd
Godfrey Hirst Carpets
GT Recycling
HeiQ Australia
Honda R&D Co. Ltd
Horizon Fuel Cells Technologies
Hydrochem Pty Ltd
Hycast Metals Pty Ltd
Imagine Intelligent Materials
IXL Metal Castings
Jemena
Keech Castings Australia Pty Ltd
Materials Solutions Pty Ltd
McConnell Dowell
METS Ignited Australia Ltd
MPC Group
Murphy Pipe and Civil Constructors (Aust) Pty Ltd
Nacap Australia
NanoCarbon Pty Ltd
Newcrest Mining Ltd
Nplex Pty Ltd
OneSteel Liberty
Planet Innovation
PPG Industries Australia Pty Ltd
Qenos Pty Ltd
QIC Protective Coatings
QuickStep Technologies Pty Ltd
ROC Oil (WA) Ltd
Rockingham Desalination Research Facility
Rural Industries R&D Corporation
Santos Geelong Pty Ltd
Seagas
Shell Refinery (Australia) Pty Ltd
Shinil Chemical Company
Stockbrands Co Pty Ltd
Studco Building Systems
Sussex Materials Solutions
ThyssenKrupp Mannex Pty Ltd
Trelleborg Engineered Systems Australia Pty Ltd
United Surface Technologies Pty Ltd
Universal Corrosion Coatings
Volgren
Weir Minerals Australia Pty Ltd
Zhik Pty Ltd

International

Baosteel (China)
Bharat Forge (India)
The Boeing Company (USA)
Carpenter Technology Ltd (USA)
Chinese Iron and Steel Research Institute
Cytec (Canada)
Data M Sheet Metal Solutions (Germany)
Donaldson Co (USA)
Dongfang Turbine Co (China)
DowAksa (Turkey, USA)
Esquel (Hong Kong)
Ford USA
General Motors (USA)
HeiQ Materials AG (Switzerland)
Holding Company Composites (Russia)
Hydro-Quebec (Canada)
Hyundai Motor Company (South Korea)
Jiangsu Shisong New Materia Technology Co Ltd (China)
LG Chem Ltd
Logistik Unicorp (Canada)
Multimatic (Canada)
Metallicum Inc (USA)
Office of Naval Research – Global (USA)
Polygauss Ltd (UK)
POSCO (South Korea)
SABIC Global Technologies
Safran Power Units (France)
Seeyao Electronics Company Ltd (China)
Shangdong Ruyi Woollen Textile Co Ltd (China)
Sichuan ShangZhiDeng New Materials Co (China)
Stora Enso Oyj (Finland)
Straumann Pty Ltd (Switzerland)
Tata Steel (India)
Tecnalia (Spain)
Terves Inc (USA)
Toyota Motor Engineering & Manufacturing (USA)
Universal Alloy Corporation (USA)
US Air Force Office of Scientific Research (USA)
US Asian Office of Aerospace Research and Development (USA)
US Army International Technology Center, Pacific (USA)
Wuhan Iron and Steel (Group) Corporation (China)
Yuntong Nanomaterials Technology Co. Ltd

Students

a

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Md Abdullah Al Faruque
Danah Al-Masri
Francois-Marie Allioux
Ajesh Antony
Joel Awuah
San Seint Aye

b

Steven Babaniaris
Ehsan Bahrami Motlagh
Kathleen Beggs
Srdan Begic
Devangana Bhuyan
Shannon Biddulph
Ilias Bikmukhametov
Rachel Brokenshire
Guillaume Bruel
Karmjeet Buttar

c

Yuying Cao
Erwan Castanet
Cheng Chen
Xiao Chen
Xingyu Chen
Jun Cheng
Andrew Church
Jerome Cornu

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Saeed Dadvar
Aref Daneshfar
Baris Demir
Aditya Deole
Elise Des Ligneris
Sharmistha Dhara
Martina Di Venere

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Ahmad Erfani Moghadam
Daniel Eyckens

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Seyed Fakhrhoseini
Aleksey Falin
Ye Fan
Ehsan Farabi
Shammi Ferdousi
David Fox
Iris Fox
Sida Fu

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Houlei Gan
Wei Gan
Shiromani Gangoda Desinghege
Laura Garcia Quintana
Razieh Ghaderi
Mahmoud Ghandehari Ferdowsi
Sadegh Ghanei
Vahide Ghanooni Ahmadabadi
Prashant Gharal
Sreeraj Gopi
Vinothkumar Govindaraj
Jarret Grout
Guangwu Guan
Haoguan Gui
Isuru Eranda Gunathilaka
Min Guo

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Nima Haghdadi
Noman Haleem
Qi Han
Andreas Hendlemeier
Samantha Hockey
Seyyed Hosseini

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Jahidul Islam

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Lu Jiang
Shan Jiang
Rahul John

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Monalisa Kalita
Vinay Kandagal
Hassan Khosroshahi
Zahra Komeily
Abhishek Kumar
Andreas Kupke

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Milad Laghaei
Mauricio Latino
Nguyen Le
Daiqi Li
Zhen Li
Yujia Liang
Yuchen Liu
Pascal Lordat
Oceane Louppe
Xi Lu
Mengying Luo

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Maxime Maghe
James Maina
Faezeh Makhlooghiazad
Mohammad Maniruzzaman
Pierre Martin
Srikanth Mateti
Jonathan McDonald
Andrey Medvedev
Andrea Merenda
Anne Katrin Mester
Hadi Mohamadi Azghandi
Sepehr Moradi
Isuru Adikari Mudiyanselage
Akbar Mostaani

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Kyle Nicholson

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Raudhah Othman

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Aneesa Padinjakkara
Urbi Pal
Vishwanath Panangipalli
Divija Pandel
Priya Pandey
Vishal Pandya
Prudvi Paresi
Jonathan Partington
Prashant Pathak
Thushan Pathirana
Yu Peng
Kalani Periyapperuma
Sri Balaji Ponraj
Cameron Pope
Adrien Pradeau
James Preston
Keiran Pringle
Manish Purushottam Meshram

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Shyama Ranade
Jun Rao
Natalie Riley
Matthew Russo

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Gourab Saha
Laura Sanchez Cupido
Priyanka Saxena
Shauna Seneviratne
Seyed Mohsen Seraji
Mirshahin Seyedsaleh
Vignesh Shanbhag
Nishat Sharma
Kamyar Shirvani Moghaddam
Sanjeev Shukla
Yuyu Su
Irin Sultana
Samuel Swan

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Arun Thandaserry
Abuzar Taheri
Sithila Theminimulla

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Mohammad Uddin
Rameshkumar Varma

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Lakshmi Vazhapully
Meenakshi Verma

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Guang Wang
Huan Wang
Jiemin Wang
Jingshi Wang
Jun Wang
Ke Wang
Zhiyu Wang
Xin Wei
Daniel Whyte
Andrea Wilde

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Liangjun Xia
Wanjie Xie

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Ramdayal Yadav
Guilong Yan
Chen Yang
Fangli Yang
Ya Yao
Xin Yu

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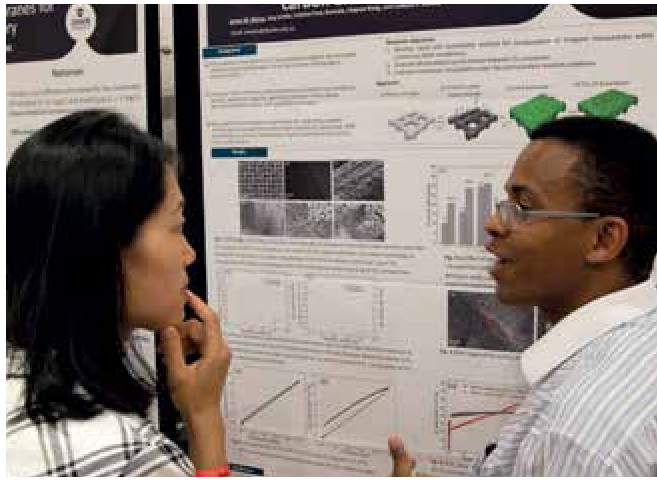
Beini Zeng
Jizhen Zhang
Jun Zhang
Liangzhu Zhang
Peng Zhang
Tao Zhang
Zhong Zhao
Yang Zhou
Yundong Zhou

Above: *Victorian Minister for Trade and Investment Philip Dalidakis and IFM student Nima Haghdadi - finalist in the Victorian International Education awards.*



Above: *Dr Jinfeng Wang and PhD student James Maina at the IFM research conference.* ***Top:*** *Staff and students get together for a social game of football.*

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